CLAIMS

We claim:

1. A device for producing a reducing gas, comprising:

a fuel injector and a catalytic zone, wherein the catalytic zone comprises an oxidation catalyst and a reforming catalyst,

wherein said fuel injector is configured to inject fuel into at least a portion of an oxygen containing gas stream upstream from said catalytic zone to provide rich and lean zones in said gas stream when said gas stream flows through said catalytic zone.

2. A device according to claim 1, wherein the device is configured such that as a rich zone in an oxygen containing gas stream flows through the catalytic zone, a portion of the fuel in the rich zone is oxidized on the oxidation catalyst and at least a portion of the remaining fuel in the rich zone is reformed on the reforming catalyst, thereby producing a reducing gas stream.

3. A device according to claim 2, further comprising a reservoir comprising a hydrocarbon fuel, wherein said reservoir is in fluid communication with said fuel injector, and wherein said reducing gas stream comprises H_2 and CO.

4. A device according to claim 3, wherein the fuel injector is adapted to introduce the hydrocarbon fuel to an oxygen containing gas stream discontinuously to form alternating rich and lean zones.

5. A device according to claim 3, wherein the fuel injector is adapted to introduce the hydrocarbon fuel to a portion of an oxygen containing gas stream essentially continuously to form a rich zone, and wherein the device is configured

such that the portion of the catalytic zone through which the rich zone flows varies over time.

6. A device according to claim 3, wherein the hydrocarbon fuel is selected from the group consisting of gaseous, liquid, oxygenated, nitrogen containing, and sulfur containing hydrocarbons.

7. A device according to claim 3, wherein the hydrocarbon fuel is selected from the group consisting of gasoline and diesel fuel.

8. A device according to claim 1, wherein said catalytic zone comprises at least one monolithic structure.

9. A device according to claim 8, wherein the monolithic structure comprises a plurality of channels.

10. A device according to claim 8, wherein the monolithic structure comprises metal.

11. A device according to claim 8, wherein the monolithic structure comprises a ceramic material.

12. A device according to claim 1, configured such that when rich and lean zones of an oxygen containing gas stream flow through the catalytic zone, the temperature of the catalytic zone is maintained at about 450 to about 1000° C.

13. A device according to claim 4, wherein the fuel injector is adapted to inject fuel with a rich-lean periodicity of about 0.1 to about 10 seconds, wherein the

rich portion of a rich-lean period extends over about 10 to about 90% of said rich-lean period.

14. A device according to claim 1, further comprising a heater or heat exchanger upstream from the catalytic zone, wherein said heater or heat exchanger is in gas flow communication with the catalytic zone.

15. A device according to claim 1, further comprising a pre-oxidation catalyst downstream from said fuel injector and upstream from said catalytic zone, wherein said pre-oxidation catalyst comprises an oxidation catalyst, wherein said fuel injector is configured to introduce fuel to at least a portion of an oxygen containing gas stream upstream from said pre-oxidation catalyst, such that when said gas stream flows through the pre-oxidation catalyst, at least a portion of the fuel introduced by the fuel injector is oxidized, thereby heating the gas stream.

16. A device according to claim 15, wherein said device further comprises a mixer downstream from said pre-oxidation catalyst and upstream from said catalytic zone, wherein the device is configured such that a portion of the fuel introduced by the fuel injector and flowing through said pre-oxidation catalyst is vaporized, wherein said mixer is configured to mix said vaporized fuel in said gas stream in a predominantly radial fashion.

17. A device according to claim 16, wherein the pre-oxidation catalyst is coated on the inner walls of a fraction of the channels of a monolithic catalyst structure.

18. A device according to claim 17, wherein said fraction is about 20 to about 80%.

19. A device for reducing nitrogen oxide (NO_X) content in oxygen-containing emissions of a lean burn engine, said device comprising:

a fuel injector and a first catalytic zone, wherein the first catalytic zone comprises an oxidation catalyst and a reforming catalyst, and wherein said fuel injector is configured to inject fuel into at least a portion of the oxygen containing exhaust stream from a lean burn engine upstream from said catalytic zone to provide rich and lean zones in said exhaust stream when said exhaust stream flows through said first catalytic zone, and

a second catalytic zone downstream from said first catalytic zone and comprising a catalyst capable of reducing NO_X to N_2 in the presence of a reducing gas.

20. A device according to claim 19, wherein the device is configured such that as a rich zone in an oxygen containing gas stream flows through the first catalytic zone, a portion of the fuel in the rich zone is oxidized on the oxidation catalyst and at least a portion of the remaining fuel in the rich zone is reformed on the reforming catalyst, thereby producing a reducing gas stream, and wherein the device is configured such that at least a portion of the exhaust stream and at least a portion of the reducing gas stream produced in the first catalytic zone flow through the second catalytic zone, wherein when said exhaust stream and said reducing gas streams flow through the second catalytic zone, NO_X is reduced to N_2 on the catalyst in the second catalytic zone.

21. A device according to claim 20, further comprising a reservoir comprising a hydrocarbon fuel, wherein said reservoir is in fluid communication with said fuel injector, and wherein said reducing gas stream comprises H_2 and CO.

22. A device according to claim 21, wherein the fuel injector is adapted to introduce the hydrocarbon fuel to an oxygen containing gas stream discontinuously to form alternating rich and lean zones.

23. A device according to claim 21, wherein the fuel injector is adapted to introduce the hydrocarbon fuel to a portion of an oxygen containing gas stream essentially continuously to form a rich zone, and wherein the device is configured such that the portion of the first catalytic zone through which the rich zone flows varies over time.

24. A device according to claim 19, wherein said lean burn engine is a diesel engine.

25. A device according to claim 21, wherein said hydrocarbon fuel is diesel fuel.

26. A device according to claim 23, wherein the device is configured such that a portion of the exhaust stream is diverted as a slipstream upstream from said first catalytic zone, and wherein said fuel injector is configured to inject fuel into the slipstream upstream from said first catalytic zone.

27. A device according to claim 26, wherein the device is configured such that about 5 to about 25% of the exhaust stream by volume is diverted into the slipstream.

28. A device according to claim 19, further comprising a controller, wherein the injection of fuel is controlled as a function selected from the group consisting of exhaust NO_X concentration, exhaust O_2 concentration, engine rpm,

engine torque, engine turbocharger boost, engine intake air flow rate, exhaust intake flow rate, exhaust flow rate, and exhaust temperature.

29. A device according to claim 19, further comprising a controller, wherein the injection of fuel is controlled as a function of exhaust NO_X concentration, wherein the NO_X concentration is determined by at least one NO_X sensor in the exhaust stream.

30. A device according to claim 19, wherein said first catalytic zone comprises at least one monolithic structure.

31. A device according to claim 30, wherein the monolithic structure comprises a plurality of channels.

32. A device according to claim 30, wherein the monolithic structure comprises metal.

33. A device according to claim 30, wherein the monolithic structure comprises a ceramic material.

34. A device according to claim 19, configured such that when rich and lean zones of an oxygen containing gas stream flow through the first catalytic zone, the temperature of the first catalytic zone is maintained at about 450 to about 1000° C.

35. A device according to claim 22, wherein the fuel injector is adapted to inject fuel with a rich-lean periodicity of about 0.1 to about 10 seconds, wherein the

rich portion of a rich-lean period extends over about 10 to about 90% of said rich-lean period.

36. A device according to claim 19, wherein said device is adapted for use in a vehicle that comprises a lean burn engine.

37. A device according to claim 36, wherein said lean burn engine is a diesel engine.

38. A vehicle comprising a device according to claim 19, wherein said device is in contact with at least a portion of the exhaust stream from a lean burn engine on a vehicle.

39. A vehicle according to claim 38, wherein said lean burn engine is a diesel engine.

40. A process for producing a reducing gas, comprising:

introducing a fuel into at least a portion of a gas stream comprising O_2, thereby creating rich and lean zones in said gas stream, wherein a portion of the fuel in a rich zone is oxidized and wherein at least a portion of the remaining fuel in the rich zone is reformed, thereby producing a reducing gas.

41. A process according to claim 40, wherein the rich and lean zones of the gas stream flow through a catalytic zone that comprises an oxidation catalyst and a reforming catalyst, wherein a portion of the fuel in a rich zone of the gas stream is oxidized on the oxidation catalyst and at least a portion of the remaining fuel in a rich zone is reformed on the reforming catalyst.

42. A process according to claim 41, wherein said fuel is a hydrocarbon fuel and said reducing gas comprises H_2 and CO.

43. A process according to claim 42, wherein said hydrocarbon fuel is introduced to the gas stream discontinuously to form alternating rich and lean zones.

44. A process according to claim 42, wherein said hydrocarbon fuel is introduced to a portion of the gas stream essentially continuously to form a rich zone, wherein said rich zone of the gas stream flows through a portion of said catalytic zone, wherein said portion of the catalytic zone is varied over time.

45. A process according to claim 40, wherein lean zones do not comprise fuel.

46. A process according to claim 40, wherein lean zones comprises fuel at an equivalence ratio less than 1.

47. A process according to claim 40, wherein the temperature of the catalytic zone is maintained at about 450 to about 1000° C.

48. A device according to claim 43, wherein the fuel is introduced with a rich-lean periodicity of about 0.1 to about 10 seconds, and wherein a rich period extends over about 10 to about 90% of said rich-lean period.

49. A process for reducing NO_X content in oxygen-containing emissions of a lean burn engine, said process comprising:

introducing a fuel into at least a portion of the oxygen containing exhaust stream of a lean burn engine, thereby creating rich and lean zones in said exhaust

stream, wherein a portion of the fuel in a rich zone is oxidized and wherein at least a portion of the remaining fuel in the rich zone is reformed, thereby producing a reducing gas, and

using at least a portion of said reducing gas to reduce NO_X in said exhaust stream to N_2 on a catalyst.

50. A process according to claim 49, wherein said the rich and lean zones in the exhaust stream flow through a first catalytic zone downstream from said fuel injector, wherein the first catalytic zone comprises an oxidation catalyst and a reforming catalyst, and wherein a portion of the fuel in a rich zone of the exhaust stream is oxidized on the oxidation catalyst and at least a portion of the remaining fuel in a rich zone is reformed on the reforming catalyst, thereby producing a reducing gas,

and wherein at least a portion of the reducing gas is introduced into at least a portion of the exhaust stream flowing through a second catalytic zone downstream from said first catalytic zone, wherein said second catalytic zone comprises a catalyst capable of reducing NO_X to N_2 in the presence of said reducing gas, and wherein NO_X is reduced to N_2 in said second catalytic zone.

51. A process according to claim 50, wherein said fuel is a hydrocarbon fuel and said reducing gas comprises H_2 and CO.

52. A process according to claim 51, wherein said hydrocarbon fuel is introduced to the gas stream discontinuously to form alternating rich and lean zones.

53. A process according to claim 51, wherein said hydrocarbon fuel is introduced to a portion of the gas stream essentially continuously to form a rich zone,

wherein said rich zone of the gas stream flows through a portion of said catalytic zone, wherein said portion of the catalytic zone is varied over time.

54. A process according to claim 49, wherein lean zones do not comprise fuel.

55. A process according to claim 49, wherein lean zones comprises fuel at an equivalence ratio less than 1.

56. A process according to claim 49, wherein the temperature of the catalytic zone is maintained at about 450 to about 1000° C.

57. A device according to claim 52, wherein the fuel is introduced with a rich-lean periodicity of about 0.1 to about 10 seconds, and wherein a rich period extends over about 10 to about 90% of said rich-lean period.

58. A process according to claim 49, wherein said lean burn engine is a diesel engine.

59. A process according to claim 51, wherein said hydrocarbon fuel is diesel fuel.

60. A process according to claim 50, wherein said portion of said exhaust stream flowing through said first catalytic zone is diverted as a slipstream upstream from said first catalytic zone, wherein said hydrocarbon fuel is injected into the slipstream.

61. A process according to claim 60, wherein about 5 to about 25% by volume of the exhaust stream is diverted into the slipstream.

62. A catalyst composition for producing H_2 and CO, comprising an oxidation catalyst and a reforming catalyst.

63. A monolithic structure comprising the catalyst composition of claim 62.

64. A device according to claim 28, wherein the device is downstream from a lean burn engine that comprises an engine control unit, and wherein the controller is incorporated into the engine control unit.

65. A device according to claim 29, wherein the device is downstream from a lean burn engine that comprises an engine control unit, and wherein the controller is incorporated into the engine control unit.